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UNITED STATES
DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
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QUESTIONS AND ANSWERS ON PROPANE AND BUTANE FUELS

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J. F. BARKLEY

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

QUESTIONS AND ANSWERS ON PROPANE AND BUTANE FUELS[1]

By J. F. Barkley[2]

FOREWORD

The following questions and answers were prepared principally to supply information in answer to general inquiries received by the Bureau from those contemplating the use of propane and butane fuels. Primary or basic information only is covered; this usually gives enough guidance for most inquirers. To those who wish information of the treatise type, the handbook, Butane-Propane Gases, published by the Jenkins Publications, Inc., 1709 West 8th Street, Los Angeles 14, Calif., is suggested.

ACKNOWLEDGMENTS

The author greatly appreciates the helpful assistance of C. F. Rogers, J. C. Kjerner, and William Thompson, of the Pacific Gas Corp. and the permission given by the American Meter Co. to use figure 5 and by the Butane-Propane News to use figure 8, Table 3 was taken from the handbook, Butane-Propane Gases, 1947, which was also a source of general information.

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[1] Work on manuscript completed April 12, 1949. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines I. C. 7519, "Questions and Answers on Propane and Butane Fuels".

[2] Chief, Fuels Utilization Branch, Bureau of Mines, U. S. Department of the Interior.

1. What are propane and butane fuels?

Propane and butane fuels are petroleum products somewhat lighter in weight and much more readily gasified than gasoline. Such a fuel is often called "liquefied petroleum gas", or "LP-gas"; at ordinary atmospheric temperatures and pressures the fuel exists as a gas, but when subjected to pressure it liquefies readily. This convenient characteristic makes possible its use as an easily burnable gas and its storage and transportation in concentrated form as a liquid under pressure. Liquefied petroleum gas is sold under many trade names.

2. How are liquefied petroleum gases obtained?

Liquefied petroleum gases occur in the earth with natural gas and crude oil and are obtained from them by various methods. Figure 1 is a diagram indicating a method. Some plants, called recycling plants, bring "wet" natural gas to the surface where the liquids are absorbed, the "dry" natural gas being returned to the earth to be saturated with another load of liquids. Much LP-gas is obtained as a product of oil refineries where crude oil is processed in producing gasoline, kerosine, and fuel oil.

3. How do propane and butane differ?

Propane is somewhat lighter, gasifies at a lower temperature, and has less heat value (B.t.u.) per cu. ft. than butane. The following table gives approximate values for various properties of propane and of normal butane on the basis of a laboratory quality product:

Table of Properties

Property	Propane	Normal Butane
1. Specific gravity of liquid at 60°F., water = 1.00	0.509	0.584
2. Vapor pressure, lb. per square in. gage		
At 60°F	92	12
At 100°F	172	37
3. Lb. per gal. of liquid at 60°F., and storage-tank pressure (vapor pressure at 60°F.)	4.24	4.86
4. Boiling point of liquid at atmospheric pressure, °F	-44°	32°
5. Cu. ft. of gas (60°F., atmospheric pressure) per lb. of liquid	8.59	6.51

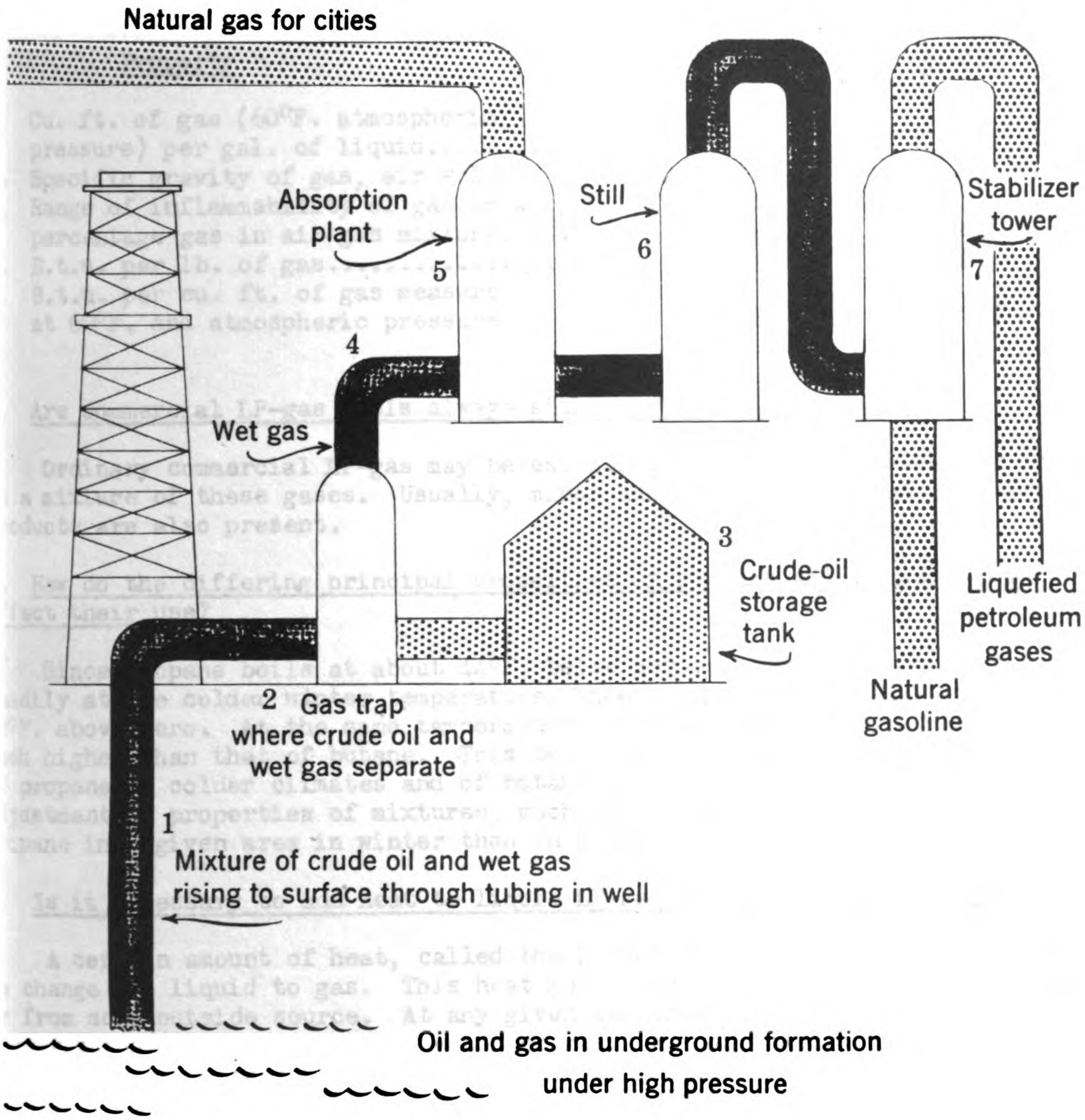
Natural gas for cities
Absorption plant
5
Still
6
Stabilizer tower
7
4
Wet gas
3
Crude-oil storage tank
Liquefied petroleum gases
Natural gasoline
2 Gas trap where crude oil and wet gas separate
1
Mixture of crude oil and wet gas rising to surface through tubing in well
Oil and gas in underground formation under high pressure

Figure 1. - Diagram of a method of obtaining liquefied petroleum gases from crude oil and natural gas.

Table of Properties (cont'd.)

Property	Propane	Normal Butane
6. Cu. ft. of gas (60°F. atmospheric pressure) per gal. of liquid..........	36.5	31.8
7. Specific gravity of gas, air = 1.00	1.52	2.00
8. Range of inflammability of gas in air, percentage gas in air-gas mixture.....	2.4 to 9.5	1.8 to 8.4
9. B.t.u. per lb. of gas..................	21,600	21,300
10. B.t.u. per cu. ft. of gas measured at 60°F. and atmospheric pressure	2,520	3,270

4. Are commercial LP-gas fuels always either propane or butane?

Ordinary commercial LP-gas may be essentially propane or butane, or it may be a mixture of these gases. Usually, minor amounts of other similar petroleum products are also present.

5. How do the differing principal properties of propane and butane fuels affect their use?

Since propane boils at about 44°F. below zero, it supplies gas much more readily at the colder winter temperatures than butane, which boils at about 32°F. above zero. At the same temperature, the vapor pressure of propane is much higher than that of butane. This tends to result in relatively more use of propane in colder climates and of butane in warmer climates. It also permits adjustment of properties of mixtures, such as the use of higher percentages of propane in a given area in winter than in summer.

6. Is it necessary to add heat to liquid LP-gas to make it become a gas?

A certain amount of heat, called the latent heat of evaporation, is required to change the liquid to gas. This heat must come either from the liquid itself or from some outside source. At any given temperature of the liquid, there is a corresponding pressure of the vapor or gas. As the temperature decreases the vapor pressure decreases. This means that if gas is taken from a container and no heat comes from any external source, the liquid temperature would drop from evaporation of gas to replace that taken. The pressure of the vapor would, therefore, decrease, resulting in less tank pressure. To what extent a drop in tank pressure is critical in the use of the gas depends upon the installation and upon general operating conditions. For example, in a typical consumer installation the gas is used at a much lower pressure than the tank pressure. This lower pressure is obtained by using a special valve, called a pressure-reducing valve, which is designed to hold a constant low pressure in the receiving gas line even though the high pressure of the gas entering the valve varies over a considerable range. Usually some heat goes into the liquid in the tank from the general surroundings; for example, a tank set in the open may receive heat from the air and the sun.

It must be decided for each installation whether or not some controlled external source of heat must be used. Ordinarily the small domestic installation, particularly when propane is used, requires no equipment for heating the liquid, except in very cold climates. Where heat is required, as with the larger installations, it may come from various sources, such as steam, hot water, or gas-burning heaters. Figure 2 shows one type of "vaporizer" designed to use the gas itself for heating and to maintain a constant chosen temperature of the liquid.

7. What safety precautions must be observed in handling LP-gas?

As with other readily combustible fluid fuels, there are usually local or State government regulations covering design and installation of LP-gas equipment, so that the user's safety is adequately protected. The National Board of Fire Underwriters at 85 John Street, New York 7, N. Y.; at 222 West Adams Street, Chicago 6, Ill.; and at Merchants Exchange Building, San Francisco 4, Calif., issues NBFU Pamphlet 58 (January 1947) entitled, "Standards for the Design, Installation, and Construction of Containers and Pertinent Equipment for the Storage and Handling of Liquefied Petroleum Gases." Codes for constructing containers have been drawn up by the Interstate Commerce Commission, the American Society of Mechanical Engineers, and a joint committee of the American Petroleum Institute and the American Society of Mechanical Engineers. Even if butane is to be used, consideration should always be given to installing containers that will take the high pressure of propane if it or higher-pressure mixtures might be used at some time. Storage tanks of ample size should be provided, particularly for domestic installations. Safety relief valves of proper sizes must be provided, and containers cannot be filled completely with liquid fuel.

Containers and first-stage regulating equipment are installed, in accordance with regulations, a given distance from buildings, particular attention being given the possibilities of containers being struck by vehicles and also to any building openings that might be below such equipment. LP-gas in the vapor phase is heavier than air and tends to settle to the ground. It is desirable that distances from buildings be such that any escaping vapor will mix readily with enough air so that an ignitible mixture will not enter the building. Care should be taken in positioning any safety relief fittings that the possible discharge of gas from them will not create hazards. Cylinder foundations preferably should

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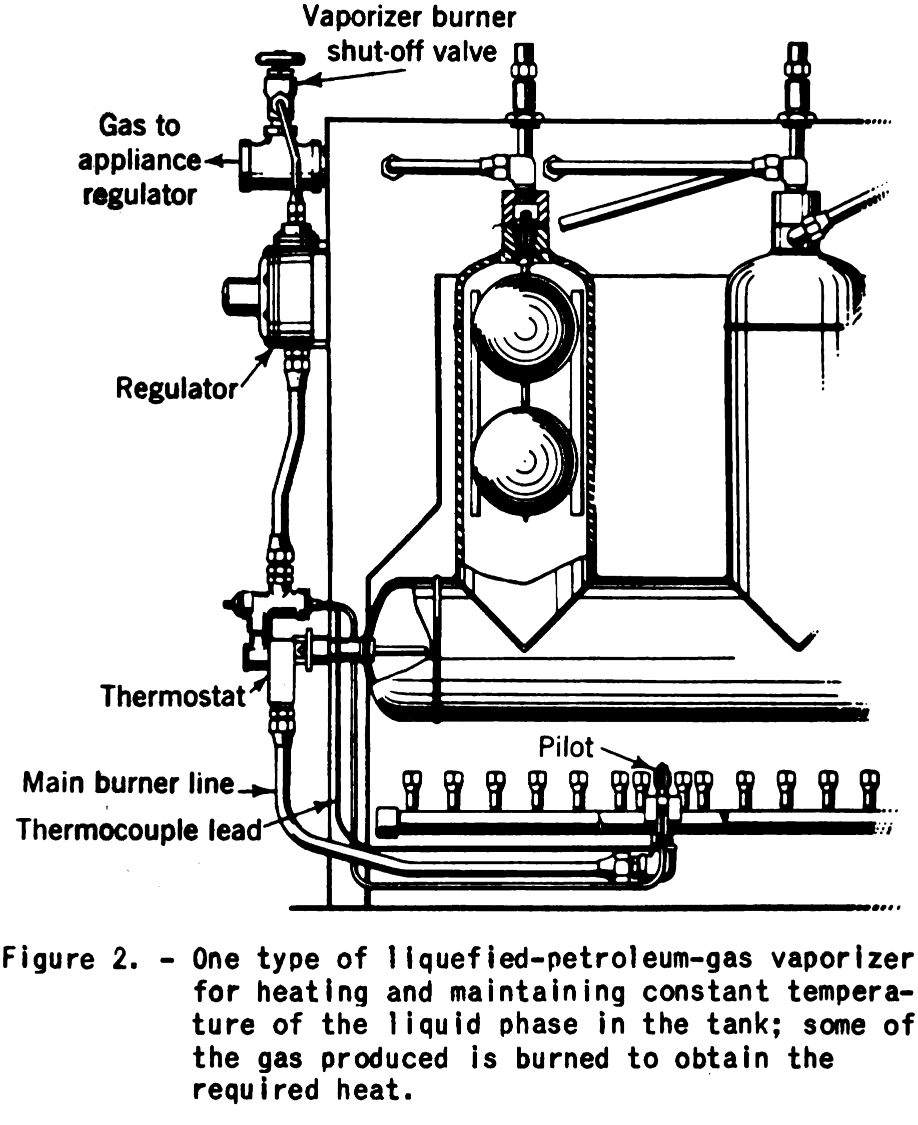

Figure 2. - One type of liquefied-petroleum-gas vaporizer for heating and maintaining constant temperature of the liquid phase in the tank; some of the gas produced is burned to obtain the required heat.

be of concrete to avoid settling; flexible connections to the fixed piping are desirable to prevent possible breakage of piping in case of cylinder movement.

LP-gas in the liquid phase is not piped into buildings unless such buildings are specifically designed to house such equipment as vaporizers, mixing devices, pressure reducers, or internal-combustion engines; LP-gas in the vapor phase should not be piped into dwellings at more than permitted pressures. All electrical equipment used must meet safety requirements. To permit the presence of the vapor to be detected readily an odorizing agent is added to LP-gas; this is required by law in many States. Users should be acquainted with the odor so that they may detect leakage readily. If leakage is detected, all gas flames and any other possible source of ignition should be cut off; sparks from electrical equipment, including possible sparking when a switch is pulled, might ignite gas. The source of leakage should be located as soon as possible. The National Conservation Bureau of the Association of Casualty and Surety Companies, 60 John St., New York City, has issued a series of pamphlets on safety in the use of LP-gas.

8. How is LP-gas transported?

Some 20 years ago the only facilities for transporting LP-gas were Interstate Commerce Commission approved cylinders, often termed "bottled-gas" cylinders. Such cylinders, ranging in size from 20 to 300 pounds capacity of gas, are still in use for some types of service, particularly home use. The development of high-pressure tank cars and trucks made possible the location of bulk distributing and bottling plants near areas of large consumption and reduced the long haul on comparatively heavy cylinders. The usual practice today is to make bulk shipments of LP-gas in 8,000- to 12,000-gallon railroad tank cars or 3,000- to 8,500-gallon truck and trailer units from points of production to points of distribution. These distributing bulk plants may have one or several storage tanks ranging in size from approximately 15,000 to 30,000 gallons. Here I.C.C. cylinders may be filled for delivery to customers, or the LP-gas may be distributed in tank trucks of 550 to 5,000 gallons capacity to fill customers' on-the-premises storage tanks of 150 to 1,000 gallons capacity. Offshore marine shipments are made in I.C.C. cylinders or skid tanks carried on deck, and one pressure tanker of 35,000-barrel capacity is currently in service. Pipe lines are also used to transport LP-gas from producing areas to large bulk storage farms.

9. How is LP-gas transferred from tank car or truck to storage tank?

There are three principal methods that can be used to transfer the liquid from the delivery container to the storage tank:

(1) Gravity.
(2) Pump.
(3) Vapor compressor.

The gravity method may be used if the truck is at a higher level than the tank and a pipe line connects the vapor spaces of each. However, the gravity method is usually slow and rather undesirable. Most trucks delivering to general consumers' storage tanks are equipped to pump the liquid from the truck. Sometimes pumps are installed at storage tanks. An equalizing vapor line connection from truck to tank should be used. Figure 3 is a diagram showing the pump method. The vapor-compressor method is often used. As shown in figure 4, instead of pumping the liquid into the receiving storage tank, vapor from the storage tank is pumped into the tank car, raising its vapor pressure. This forces the liquid from the tank car through the connecting liquid line into the storage tank. The equipment is arranged so that the compressor may also pump vapor in the opposite direction. After the liquid is transferred to the storage tank, considerable remaining vapor in the tank car can then be pumped back to the storage tank.

10. Are special valves and fittings necessary for LP-gas?

Many companies specialize in valves and fittings designed for use with LP-gas and have been tested and approved. LP-gas has a solvent action on rubber, and only appropriate valve seat and gasket material should be used. Proper choice of pipe-joint compound must be made. In general, it is recommended that design of piping lay-out, choice of needed valves, etc. be made only by thoroughly experienced designers.

11. What use is made of LP-gas fuel?

In general, LP-gas may be used as fuel for any purpose where gas can be burned.

12. Is the gas always used undiluted as it evaporates from the liquid?

The gas may be used without dilution at its normal B.t.u. value or it may be used diluted with air at lower B.t.u. values. When diluted with air, the amount used for dilution is always outside the range of its inflammability, more gas being present than would form an explosive mixture.

13. Can any gas burner be used for LP-gas?

Since a "gas burner" is a device for supplying a given amount of gas mixed with chosen amounts of air, in general any gas burner can be used that can be suitably adjusted to supply correct amounts of LP-gas and of air for proper combustion under given furnace conditions. There are a variety of burners designed specifically for LP-gas; their use is ordinarily desirable. Any attempt to adapt a given burner designed and adjusted for one type of gas to burn a different type of gas or one of a different B.t.u. content should only be done

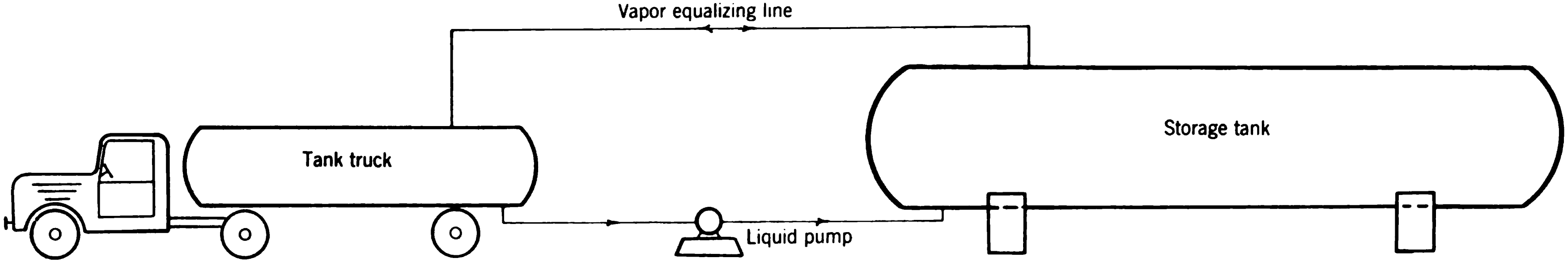

Figure 3. - Diagram of the "pump" method of transferring L. P. gas from delivery truck to storage tank.

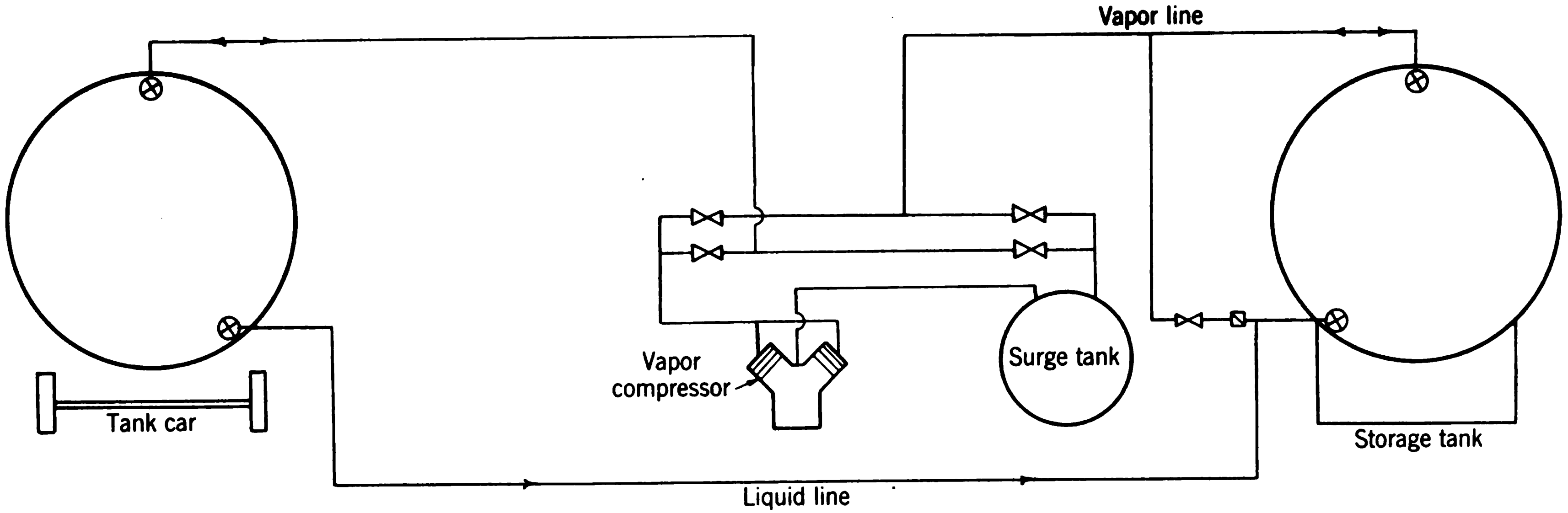

Figure 4. - Diagram of the "vapor compressor" method of transferring gas from tank car to storage tank.

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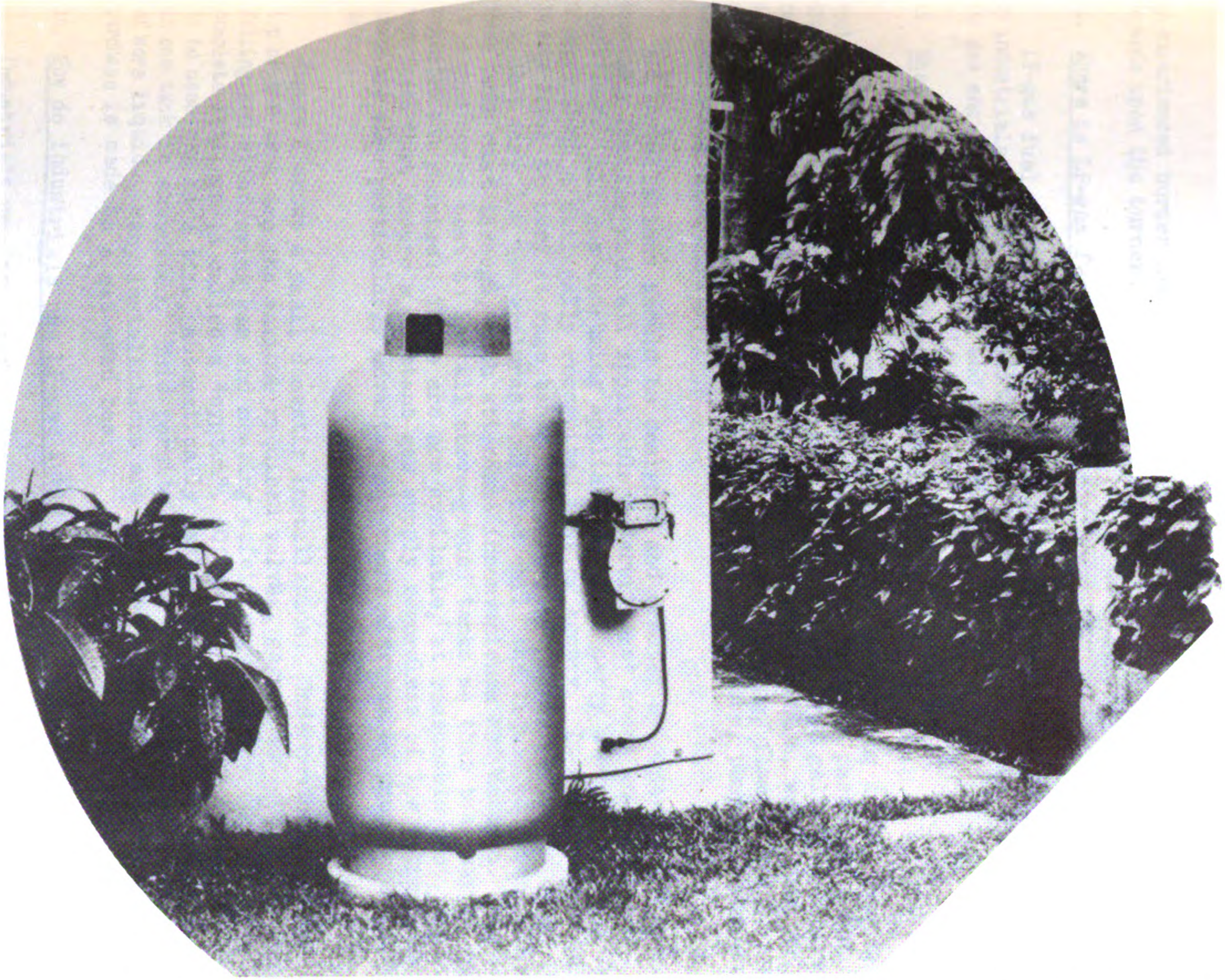

Figure 5. - Small domestic L. P. gas installation for supplying undiluted L. P. gas, showing tank and gas meter.

by experienced burner men. Whether or not it can be done satisfactorily depends upon the burner.

14. Where is LP-gas fuel being used?

LP-gas fuel is being used throughout the United States in homes, on farms, by industrials and public utilities for many heating purposes and as a fuel for gas engines both mobile and stationary.

15. What constitutes a domestic installation?

Domestic installations range in size from those having small 20-pound "bottles", for service such as supplying heating gas to a passenger automobile trailer, to those having storage tanks of several hundred gallons for farm or ranch use. The gas may be used for cooking, refrigeration, water heating, space heating, crop drying, food processing, incubating, flame weeding, and as a motor fuel for passenger automobiles, trucks, tractors, pumping equipment, and generating electricity.

All installations should be designed and erected by experienced personnel thoroughly familar with all applicable Underwriters' codes and State and local regulations. All gas-consuming appliances should carry a certificate or seal of approval of a nationally recognized testing agency. It has been the practice in some areas to bury storage tanks for safety purposes, for landscaping reasons, or so that very low temperatures would not chill the liquid too much. In time, these tanks rust through, with attendant inconvenience and hazards. In general, it is considered best to install above-ground tanks so that they may be regularly inspected and painted. There are now available, at reasonable cost, small vaporizers that assure a constant gas supply regardless of low temperatures; these are also particularly advantageous where mixtures of propane and butane are used.

Figure 5 shows a small domestic installation. Underneath the cap at the top of the tank are the various required valves, gages, and other fittings for filling and withdrawing gas and meeting safety regulations. The tank with complete fittings is called a "system". Often two tanks are installed, arranged to be used one at a time, automatically making the change-over when the liquid in one tank is exhausted. This permits greater freedom in timing the delivery of more liquid. Many installations are provided with gas meters so that the purchase is made on a gas-used basis.

16. How do industrials use LP-gas fuel?

Industrials use LP-gas fuel for a great many purposes since the burning of gas is cleanly and it is easily controlled. It is used for repairing jewelry, for heating large furnaces, for direct-flame sterilizing, incineration, space heating, etc. Often straight LP-gas is used, with all burning appliances adjusted for this gas. Where natural gas is also available, LP-gas mixed with air may be used. This permits of one adjustment of the appliances for either gas. A stand-by LP-gas installation permits burning natural gas at the lower interruptible rates usually available. The installation cost may be quickly amortized for some industrial uses by permitting important furnaces to remain in operation when the supply of natural gas fails. Figure 6 is a sketch of a typical large industrial installation showing vapor pump, storage tank, vaporizer-mixer unit, and surge tank. Figure 7 is a photograph of such an installation having the unloading station at right rear, two storage tanks, and the vaporizer-mixer and surge tank in the foreground.

17. How do public utilities use LP-gas fuel?

Public utilities use LP-gas fuel in various ways, such as:

(a) 100% town supply. Straight LP-gas is served some towns where natural gas service is not anticipated. More often an LP-gas—air mixture is served to substitute for gas from a high-cost manufactured-gas plant or to give gas service to a community pending natural gas pipe line extension. The lower-B.t.u. LP-gas—air mixture provides a substitute gas that can be used with a minimum of gas-burning appliance adjustments.

(b) Stand-by types of service. LP-gas is kept in storage to supply gas in case of pipe line or equipment failure. It is often cheaper to use LP-gas to meet winter peak loads than to construct facilities for manufactured gas that would be idle much of the year. Where local utilities are purchasing natural gas, it may be found economically desirable to lower the extreme peaks purchased by means of a LP-gas stand-by.

(c) Enrichment of low-B.t.u. manufactured gas. LP-gas may be added at the storage holder (cold enriching), or it may be run through the gas manufacturing equipment (reforming).

18. How is LP-gas used to run automobiles, tractors, and trucks?

LP-gas can be used in gas engines, either mobile or stationary, by the application of suitable auxiliaries. It burns cleanly in the engine and enters as a vapor thus minimizing oil dilution. Figure 8 is a diagram showing required tank, regulators, vaporizer, and carburetor. To use LP-gas in an

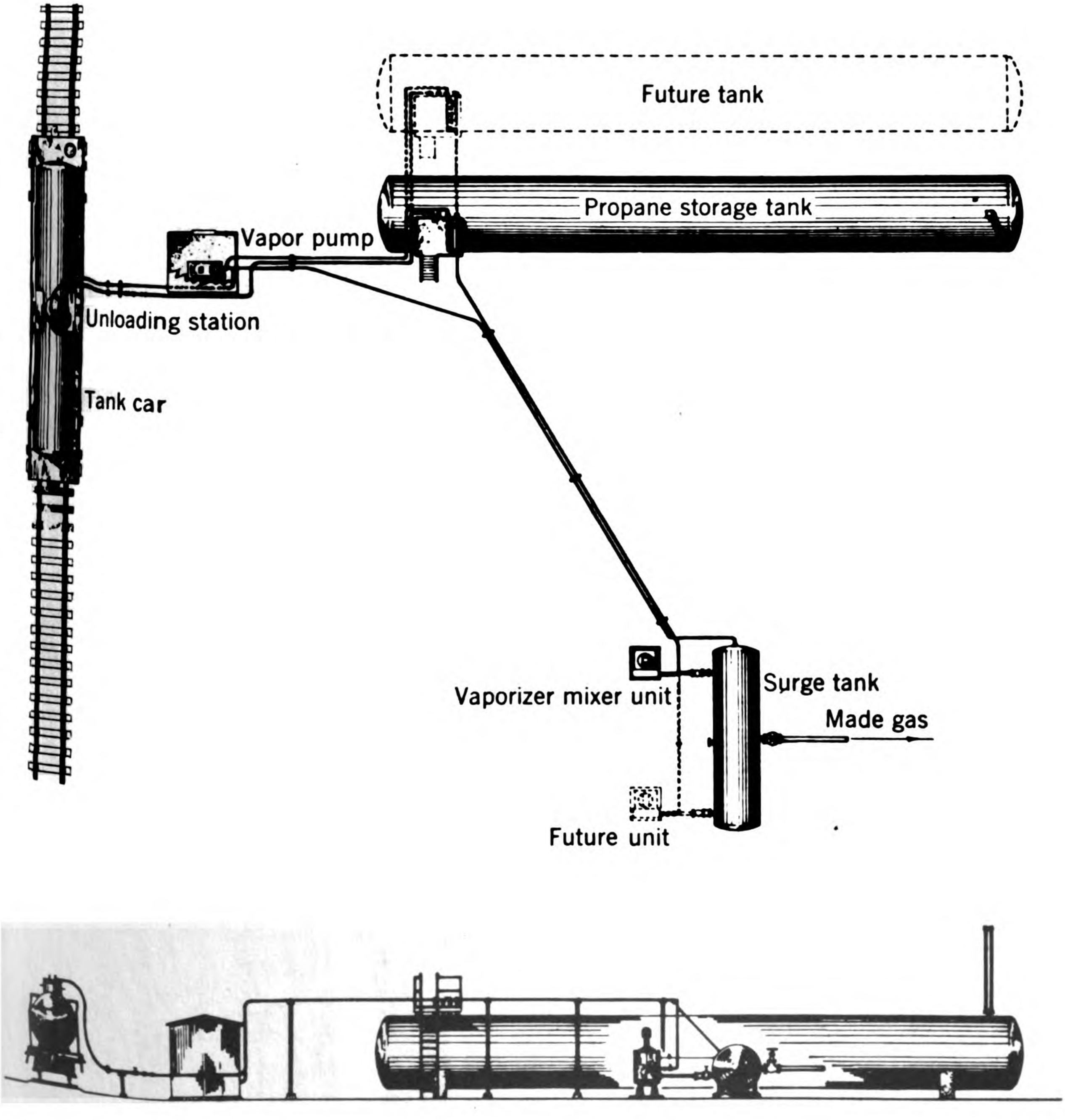

Figure 6. - Typical industrial L. P. gas installation for supplying L. P. gas mixed with air, showing vapor compressor or pump, storage tank, vaporizer-mixer unit, and surge tank.

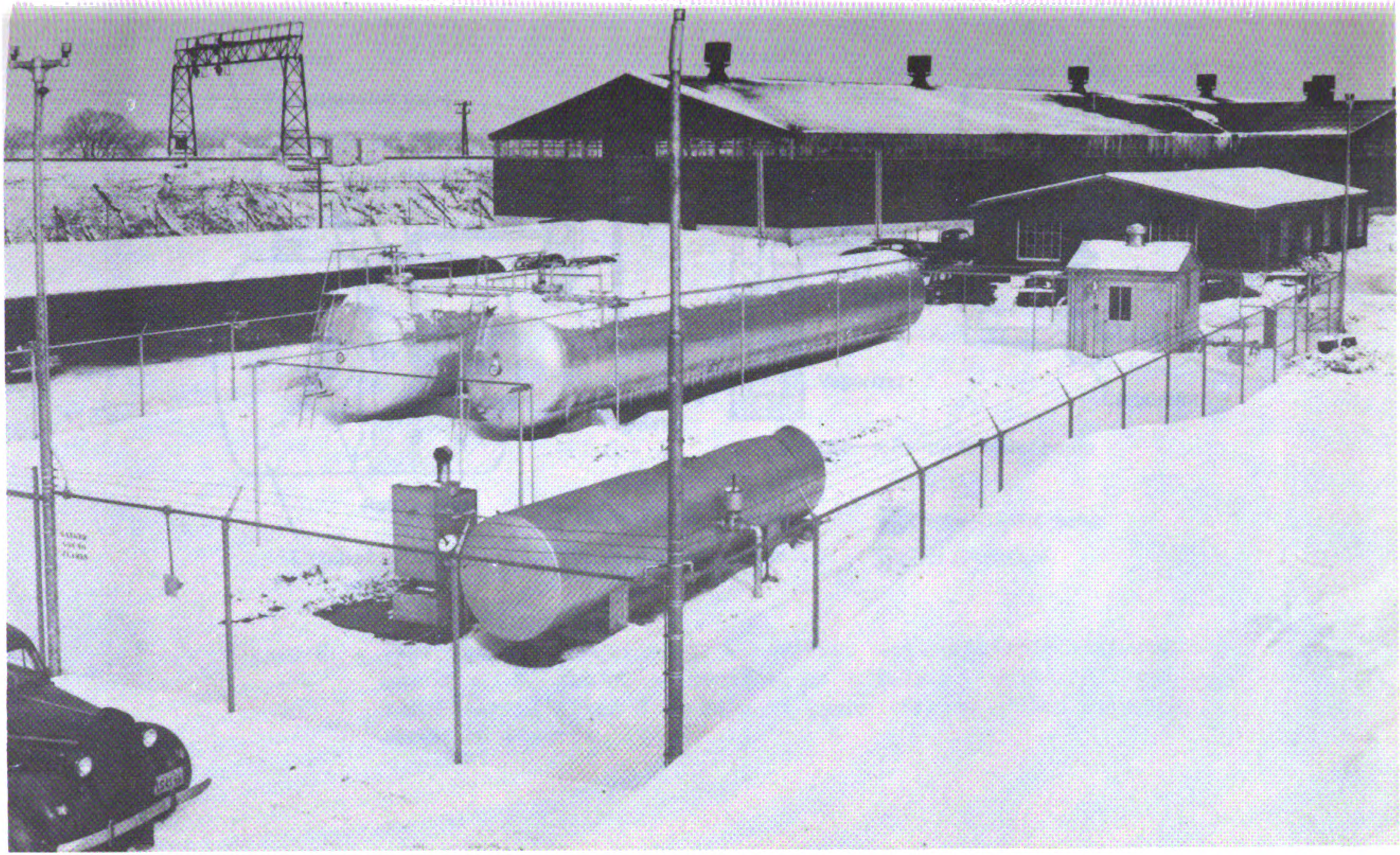

Figure 7. - Typical industrial L. P. gas installation similar to figure 6, having unloading station at right rear, two storage tanks, and the vaporizer-mixer and surge tank in the foreground.

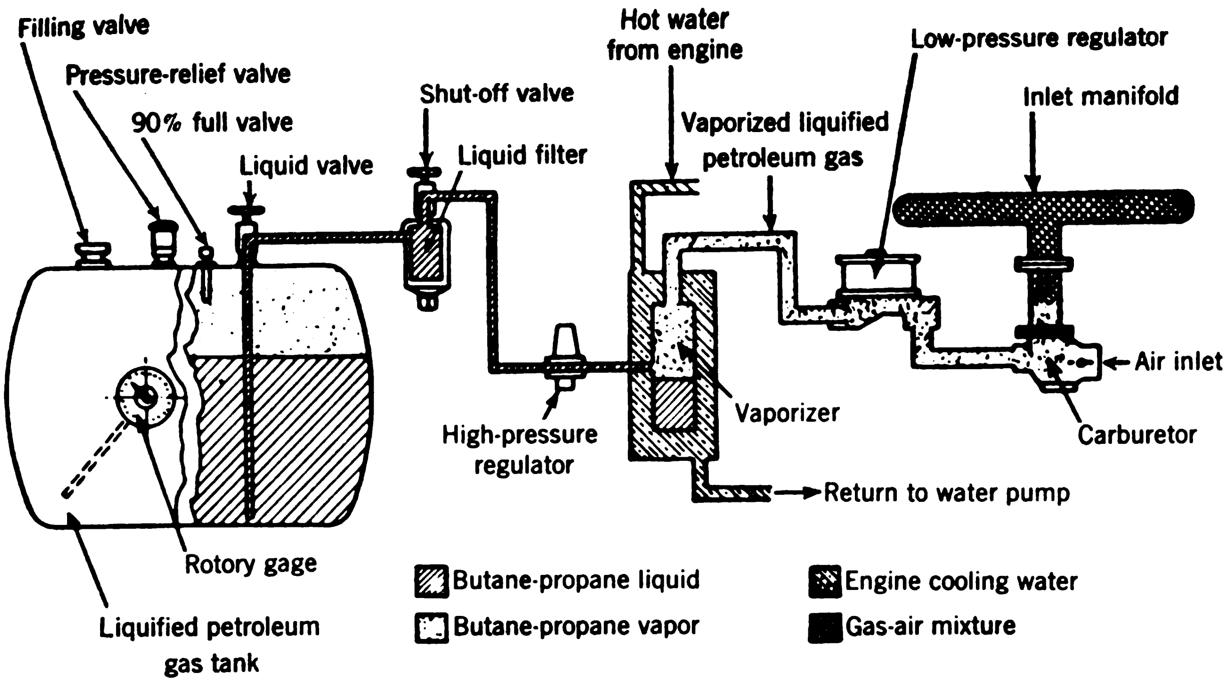

Figure 8. - Typical tank, regulators, vaporizer, and carburetor required for use of L. P. gas on automobiles or tractors. Source of heat for vaporizer is often from exhaust gases instead of hot water as shown in diagram.

automobile, a tractor, or truck now using gasoline, such equipment must be added to or substituted for its similar equipment designed for use of gasoline. Various designs of this equipment are available on the market, using hot water or engine exhaust for heating the vaporizer. Some systems permit operation on either gasoline or LP-gas by valve-throw from one set of auxiliaries to the other. Installations must be made in accordance with code regulations.

LP-gas has not become popular for use in passenger automobiles. An extra storage tank takes space - usually in the luggage compartment; refueling stations are infrequent; gasoline is readily available - special conditions must be present to make its use desirable in such automobiles. It is used considerably, however, in trucks where favorable cost conditions prevail. On farms and ranches it is being increasingly used in tractors.

19. How much LP-gas is used in the United States?

It is estimated that almost 2¼ billion gallons were used in 1947. This is about 30 percent more than used in 1946. About 52 percent of this total was used for domestic purposes. Pertinent data regarding the distribution of LP-gas by manufactured-gas companies and credited to the American Gas Association are as follows:

> Liquefied petroleum gas, as of July 1, 1948, was being delivered through mains to 301,650 consumers in 419 communities by 188 companies in 39 States.
>
> Butane-air gas and propane-air gas with heating values ranging from 525 to 1,600 B.t.u. per cu. ft. were supplied 336 communities in 37 States.
>
> A mixture of undiluted butane and propane gas with heating values of 2,800 to 3,550 B.t.u. per cu. ft. was supplied 22 communities in Arizona, California, Nevada, New Jersey, and New Mexico.
>
> Undiluted propane-gas with heating values of 2,515 to 2,550 B.t.u. per cu. ft. was supplied 61 communities in Iowa, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Mexico, North Carolina, North Dakota, Virginia, and Wisconsin.

The above statistics are taken from Bureau of Mines Mineral Market Report No. MMS 1646 on liquefied petroleum gases. Such statistical reports are issued annually.